Attraction of *Bactrocera dorsalis* (Diptera: Tephritidae) and Nontarget Insects to Methyl Eugenol Bucket Traps with Different Preservative Fluids on Oahu Island, Hawaiian Islands

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J. Econ. Entomol. 100(3): 723–729 (2007)

ABSTRACT Attraction of oriental fruit fly, *Bactrocera dorsalis* (Hendel) (Diptera: Tephritidae), and nontarget insects to preservative fluids ethylene glycol antifreeze, propylene glycol antifreeze, or mineral oil in bucket traps that contained captured decaying male oriental fruit flies, a male lure (methyl eugenol), and a toxicant (DDVP vapor insecticidal strip) were compared with dry control traps. Significantly ($P < 0.05$) greater numbers of *B. dorsalis* were captured in propylene glycol antifreeze traps than in other attractant trap types. Among attractant trap types with lowest negative impacts on nontarget insects, control traps captured significantly lower numbers of three species and one morphospecies of scavenger flies, one species of plant-feeding fly, and one species each of sweet- and lipid-feeding ants. Mineral oil traps captured significantly lower numbers of two species of scavengers flies and one morphospecies of plant-feeding fly, and one species of sweet-feeding ant. Because of the fragile nature of endemic Hawaiian insect fauna, the propylene glycol antifreeze bucket trap is best suited for use in environments (e.g., non-native habitats) where endemic species are known to be absent and mineral oil traps are more suited for minimizing insect captures in environmentally sensitive habitats.

KEY WORDS preservatives, nontarget insects, propylene glycol, ethylene glycol, mineral oil

Insect preservative or collecting fluids, such as ethylene glycol antifreeze, propylene glycol antifreeze, brine, ethanol, formaldehyde, vinegar, and water plus detergent, have been used primarily in pitfall traps (Landolt 1990, Holopainen 1992, Vanden Berghe 1992, Asquith and Kido 1994, Lemieux and Lindgren 1999, Vogt and Harsh 2003). Among these fluids, ethylene glycol was reported to reduce insect decay, predation, and escapes even after dilution by rainwater or concentration by evaporation (Lemieux and Lindgren 1999). Holopainen (1990, 1992) reported that ethylene glycol pitfall trap captures of carabid beetles was greater than that of traps containing water. However, because ethylene glycol was reported as more toxic to human cells than propylene glycol, propylene glycol antifreeze is being used as a less toxic alternative (Mochida and Gomyoda 1987, Lemieux and Lindgren 1999). In the Hawaiian Islands, previous researchers (Asquith and Kido 1994, Asquith and Burny 1998) used ethylene glycol as a preservative to remove the attractive odor of captured decaying oriental fruit fly, *Bactrocera dorsalis* (Hendel) (Diptera: Tephritidae) bodies to nontarget insects in rain protected methyl eugenol (male *B. dorsalis* lure) baited pitfall and aboveground bucket traps. However, Uchida et al. (2003) suggested that ethylene glycol was attractive to some nontarget insects and recommended mineral oil as a less attractive alternative.

Howarth (1990) reported that over a period of 70 million yr, 400 insect colonizers gave rise to >5,000 known endemic arthropod species on the most isolated islands in the world, the Hawaiian Islands. Most of the large intact native forests with associated endemic arthropods occur primarily in the uplands from ≈609 to 1,524-m elevation (Hardy 1965). During the mid-19th Century, conversion of drier native forest below 609-m elevation to grazing lands and plantations and damage to remaining native vegetation by feral ungulates resulted in a loss of numerous terrestrial ecosystems with only remnant vegetations remaining (Cuddihy 1989). Gagne (1988) reported that >25% of the endangered species and 75% of the recorded historical extinctions in the United States were species endemic to the Hawaiian Islands. *B. dorsalis* breeds primarily in the guava belt (Ripperton and Hosaka 1942), which extends from lower to middle elevations on each of the high islands in the Hawaiian chain. The primary hosts are *Psidium cattleanum* Sabine, which is prevalent in the interface of the guava belt and upland native cloud forests, and *Psidium guajava* L., which occurs in abundance in wet valleys at

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lower and middle elevations (Vargas et al. 1983). Because of the fragile nature of the endemic insect fauna in these areas, nontarget insect researchers (Howarth and Howarth 2000, Uchida et al. 2003) have subsequently suggested that fruit fly traps be modified (e.g., trap color) to reduce the number of captured nontarget insects and in particular endemic species while targeting fruit flies.

In 1999, an areawide integrated pest management (IPM) (AWPM) program (Chandler and Faust 1998, Faust and Chandler 1998) was initiated in the Hawaiian Islands to develop and implement existing IPM tools in an environmentally and economically sound manner for transfer to growers, for controlling four species of fruit flies (Diptera: Tephritidae), including the most widespread and abundant species, *B. dorsalis* (Haramoto and Bess 1970, Vargas et al. 1983). An environmental component was set up to examine the attractiveness of fruit fly attractants, including methyl eugenol, to nontarget insects. Because mass trapping with standard fruit fly bucket traps was used as a primary method for *B. dorsalis* control, our objective was to test the attractiveness of the preservative fluids ethylene glycol antifreeze and propylene glycol antifreeze, and a new fluid, mineral oil, to male *B. dorsalis* and nontarget insects. The most attractive fluid could be used for improving capture efficiency of methyl eugenol bucket traps for male *B. dorsalis* in disturbed habitats (e.g., exotic lowland forests), where endemic insects are known to be absent. Alternately, because of the fragile nature of the Hawaiian endemic insects, the least attractive fluid would be better suited for minimizing the number of endemic nontarget species and individual insects captured in standard traps placed in environmentally sensitive habitats, where *B. dorsalis* breeds in the interface between predominantly upland native vegetation and predominantly lowland introduced vegetation. Additionally, the length of field exposure of methyl eugenol traps containing an attractive fluid for maximum trapping efficiency for male *B. dorsalis* and minimum effects on nontarget insects are important considerations. Such traps would be beneficial for use in other areas, such as California, Texas, Florida, and elsewhere, when *B. dorsalis* is sporadically introduced.

Materials and Methods

Bucket traps (Uchida et al. 1996) were assembled with opaque white plastic cups (411-32-N, 0.89-ml cups, 12.0 cm (top) and 10 cm (bottom) diameter, 11.5 cm in height) and lids (PF-411, 12.1-cm-diameter lid) (Highland Plastics, Pasadena, CA), and galvanized wire handles and wick hangers. Wicks (dental cotton roll, 3.81 cm in length by 0.6 cm in diameter) (Pearsons Dental Supply, Sylmar, CA), which served as lure dispensers, were hung individually inside each trap on wire hangers beneath the plastic lids. All traps had four 2.2-cm-diameter entrance holes evenly spaced around the upper side.

Our experiment was designed as a single measure split-plot, randomized complete block and conducted within a 3.04-ha Plant Science Instructional Arboretum (Warner 1980), Waimanalo Experiment Station, University of Hawaii, Oahu Island, Hawaiian Islands. Every trap used in the current study was baited with 2 ml of a male *B. dorsalis* lure methyl eugenol (Steiner 1952), and a 2,2-dichlorovinyl dimethyl phosphate (DDVP) vapor insecticidal strip (Vaportape II insecticidal strip, 10.75% active ingredient, Hercon Environmental Company, Emigsville, PA), which was hooked to the lid next to a treatment wick. At each of four sites, a set of three treatment traps, containing the treatments, 47 ml of ethylene glycol antifreeze (Prestone Antifreeze/Coolant, Prestone Products Corporation, Danbury, CT), propylene glycol antifreeze (Prestone LowTox Antifreeze/Coolant), or mineral oil (Roberts Laboratories Inc., a subsidiary of Roberts Pharmaceutical Corp., Eaton, NJ), and a dry trap (control) without any preservative-collecting fluid were separately deployed on three trees in a straight line. The end of each line of trees was separated by 20 m. The lack of a preservative in control traps, allowed for the decomposition of captured *B. dorsalis* under field conditions. Captured insects, which contain water, would be expected to decay in mineral oil in traps and serve as sources of attraction for carrion associated insects, but the relatively high viscosity of mineral oil minimizes the release of decaying insect volatiles emanating from its surface (Kido et al. 1996, Uchida et al. 2003). Traps were hung individually on exposed tree branches ≈10 m or more apart. During a 28-d trapping period (29 August–26 September 2001), a set of traps was removed without replacement from each site every seventh day, contents in trap bottoms were each decanted into a flat pan, nontarget insects were transferred to appropriately labeled 1 dram glass vials containing lacquer thinner, and male *B. dorsalis* were scored and discarded. Later, each vial of mineral oil trap captures were bathed twice in lacquer thinner to remove all traces of mineral oil followed by absolute methanol to remove lacquer thinner, and stored in 75% methanol. Many specimens, which were unidentifiable at species level because they were undescribed or unidentified insects, were grouped by morphological similarities and are designated herein as morphospecies. Two or more unidentified morphospecies belonging to the same insect genus or family taxon were assigned species numbers sp. 1, sp. 2, and so on.

Statistical Analysis. Nontarget insect capture data were analyzed using a generalized, linear, mixed models approach and a GLIMMIX.SAS macro (Littell et al. 1996) with a log link function, which modeled count data as a Poisson distribution. Because of a large number of zeros, a constant of 0.5 was added to all counts before analysis. Taxa with all zero counts were dropped from the analysis and reported herein as zeros without confidence intervals. Depending on which covariance structure gave minimum fit statistics (Akaike's Information Criterion [AIC], a finite sample corrected version of AIC, or Schwartz's Bayesian Criterion), covariances across periods were collectively modeled with an independent, first-order autoregressive, or Banded Toeplitz structure. Both random (site

Table 1. Mean captures and 95% confidence intervals (lower and upper) of *B. dorsalis* and all nontarget insects collected over 7-, 14-, 21-, and 28-d trapping periods in ethylene glycol antifreeze-, propylene glycol antifreeze-, mineral oil-, and dry methyl eugenol-baited bucket traps in a fruit tree arboretum in Waimanalo, Oahu Island, Hawaiian Islands

Family	Species	Trapping period (d)	Ethylene glycol antifreeze	Propylene glycol antifreeze	Mineral oil	Control
Tephritidae	*Bactrocera dorsalis* (Hendel)	7	37.6 (19.9–70.9)a	19.8 (10.5–37.4)a	35.4 (17.0–74.0)a	36.5 (19.3–68.8)a
		14	71.7 (38.0–135.1)ab	204.6 (108.5–385.7)a	61.8 (32.8–116.6)ab	53.9 (28.6–101.7)b
		21	102.0 (54.1–192.3)b	650.5 (345.0–1226.8)a	134.3 (71.2–253.2)b	99.2 (52.6–187.1)b
		28	248.9 (132.0–469.4)ab	694.3 (368.2–1309.3)a	149.2 (79.1–281.4)b	220.7 (105.6–461.0)ab
Milichiidae	*Desmometopa tarsalis* Loew	7	0.0a	−0.00 (−0.40 to 2.09)a	0.01 (−0.43 to 3.35)a	−0.00 (−0.40 to 2.09)a
		14	0.0b	2.00 (0.69–4.75)a	−0.00 (−0.40 to 2.09)ab	1.66 (0.48–4.30)a
		21	0.0b	2.00 (0.69–4.75)a	1.33 (0.27–3.84)a	2.66 (1.13–5.64)a
		28	0.0b	3.00 (1.36–6.08)a	1.00 (0.08–3.39)ab	22.61(14.20–35.38)a
Phoridae	*Megaselia scalaris* (Loew)	7	−0.04 (−0.36 to 1.01)a	−0.00 (−0.35 to 1.14)a	−0.02 (−0.39 to 1.56)a	0.32 (−0.19 to 1.68)a
		14	0.87 (0.12–2.54)a	0.99 (0.17–2.79)a	−0.00 (−0.35 to 1.14)a	−0.01 (−0.35 to 1.14)a
		21	3.00 (1.33–6.19)a	2.98 (1.31–6.18)a	−0.00 (−0.35 to 1.14)b	0.65 (−0.01 to 2.23)ab
		28	13.03 (6.93–24.14)a	3.97 (1.88–7.91)ab	0.33 (−0.19 to 1.69)b	0.05 (−0.37 to 1.83)b
Lonchaeidae	*Lonchaea striatifrons* Malloch	7	0.19 (−0.40 to 4.27)a	−0.00 (−0.46 to 5.20)a	0.0a	0.0a
		14	−0.09 (−0.46 to 4.26)a	1.00 (−0.17 to 6.22)a	0.0a	0.0a
		21	1.02 (−0.13 to 5.68)b	27.00 (9.47–75.33)a	0.0b	0.0b
		28	18.93 (6.59–52.78)a	41.00 (14.15–117.01)a	0.0b	0.0b
Chloropidae	Chloropid sp. 2	7	−0.02 (−0.30 to 0.67)a	−0.02 (−0.30 to 0.67)a	0.0a	0.0a
		14	−0.02 (−0.30 to 0.67)a	−0.02 (−0.30 to 0.67)a	0.0a	0.0a
		21	−0.02 (−0.30 to 0.67)a	0.62 (0.00–1.99)a	0.0a	0.0a
		28	1.25 (0.27–3.50)a	−0.02 (−0.30 to 0.67)ab	0.0b	0.0b
Muscidae	*Atherigona orientalis* Schiner	7	0.0a	−0.03 (−0.29 to 0.57)a	0.06 (0.29–0.98)a	0.0a
		14	0.0a	0.29 (−0.13 to 1.15)a	−0.01 (−0.28 to 0.62)a	0.0a
		21	0.0b	1.54 (0.51–3.65)a	−0.01 (−0.28 to 0.62)ab	0.0b
		28	0.0a	−0.03 (−0.29 to 0.57)a	0.32 (−0.11 to 1.22)a	0.0a
Formicidae	*Monomorium floricola* (Jerdon)	7	−0.15 (−0.48 to 5.11)ab	4.83 (0.02–54.54)a	0.0b	0.0b
		14	−0.15 (−0.48 to 5.11)a	−0.25 (−0.49 to 3.53)a	0.0a	0.0a
		21	2.63 (−0.19 to 31.10)a	−0.25 (−0.49 to 3.53)a	0.0a	0.0a
		28	0.08 (−0.45 to 6.59)a	−0.25 (−0.49 to 3.53)a	0.0a	0.0a
	Technomyrmex albipes (F. Smith)	7	−0.11 (−0.41 to 1.01)a	0.33 (−0.24 to 2.12)a	−0.01 (−0.40 to 1.88)a	0.0a
		14	2.48 (0.61–7.51)a	−0.00 (−0.37 to 1.39)ab	−0.01 (−0.37 to 1.37)ab	0.0b
		21	−0.11 (−0.40 to 1.01)a	−0.00 (−0.37 to 1.39)a	0.64 (−0.11 to 2.86)a	0.0a
		28	−0.11 (−0.40 to 1.01)a	−0.00 (−0.37 to 1.39)a	0.32 (−0.24 to 2.10)a	0.0a

Captures not followed by the same letter within a row are significantly different.

and attractant trap type × site) and fixed (attractant trap type, trapping period, and attractant trap type × trapping period interaction) effects were fitted with this single measures model. Significant differences ($P < 0.05$) among attractant trap type means within trapping period were determined by individual *t*-tests (Steel and Torrie 1980). *B. dorsalis* capture data were ln transformed and analyzed using a normal theory mixed models approach for 7-, 14-, and 21-d trapping periods, and 28-d trapping period data were analyzed with PROC GENMOD. Overall tests of significance for fixed effects, least square means, and 95% upper and lower confidence intervals transformed back to original counts are reported in the present paper as positive or negative values.

Results and Discussion

Means and 95% confidence intervals for each attractant trap type by trapping period are reported for male *B. dorsalis,* four species and one morphospecies of flies, and two species of ants, which were captured in significantly ($P < 0.05$) greater numbers in one or more attractant trap type (Table 1). Although one mineral oil trap and one control trap were, respectively, missing during 7- and 28-d trapping periods, all available data were used in our statistical analyses and reported herein.

For male *B. dorsalis,* fixed effects of attractant trap type ($F = 11.75$; df = 3, 28; $P < 0.0001$) and period ($F = 47.17$, df = 3, 28; $P < 0.0001$) were significant. Methyl eugenol-baited bucket traps containing propylene glycol antifreeze captured significantly more flies than ethylene glycol antifreeze (21-d trapping period), mineral oil (21- and 28-d trapping periods), and control traps (14- and 21-d trapping periods) (Table 1). Thomas et al. (2001) who reported that propylene glycol antifreeze in aboveground flat-topped cylindrical traps baited with synthetic lures (ammonium acetate and putricene) captured significantly more *Anastrepha suspensa* (Loew) and *Anastrepha ludens* (Loew) (Diptera: Tephritidae) than traps containing water in North America. They surmised that an impurity or breakdown product of propylene glycol antifreeze was an additional source of attraction when used with the synthetic lures. Because the nature of our experiment, our data cannot verify the supposition of Thomas et al. (2001). Additionally, propylene glycol antifreeze was shown to increase attraction of carabid beetles to unbaited pit fall traps (Holopainen 1992). Hence, it seems that methyl eugenol served as a long-distance attractant and propylene glycol antifreeze or one of its impurities served as an additional attractant or enhanced the attraction of the lure. More research is needed to properly address this supposition.

Based on the foregoing discussion, propylene glycol antifreeze bucket traps are suited for field use for 7- and 14-d trapping periods as a substitute for control traps for improvement of male *B. dorsalis* trap captures in disturbed, nonsensitive habitats where endemic insects are known to be absent. In addition, because propylene glycol antifreeze also can serve as a collecting agent, potentially, eliminating the DDVP vapor insecticidal strip will remove a source of environmental contamination and a potential mammal poison. Further research is needed to determine whether propylene glycol antifreeze can be used as a suitable replacement for DDVP vapor insecticidal strip.

Total nontarget insect captures for ethylene glycol antifreeze, propylene glycol antifreeze, mineral oil, and control traps were, respectively, 34, 50, 13, and 60 for 7-d trapping periods; 50, 64, 41, and 25 for 14-d trapping periods; 79, 158, 18, and 22 for 21-d trapping periods; and 175, 210, 31, and 54 for 28-d trapping periods. Total nontarget species and morphospecies captures for ethylene glycol antifreeze, propylene glycol antifreeze, mineral oil, and control traps were, respectively, 17, 14, 6, and 16 for 7-d trapping periods; 15, 11, 19, and 11 for 14-d trapping periods; 29, 33, 12, and 11 for 21-d trapping periods; and 28, 38, 14, and 8 for 28-d trapping periods. Mineral oil traps captured the fewest nontarget insects during 7-, 21-, and 28-d trapping periods, and fewest species plus morphospecies during 7-d trapping period. Control traps captured the least number of nontarget insect individuals during a 14-d trapping period and least number of species plus morphospecies during 14-, 21-, and 28-d trapping periods. In general, it seems that mineral oil traps are least attractive to nontarget insect individuals, but control traps are least attractive to nontarget insect taxa. Because both mineral oil and control traps are the least attractive to both nontarget insects and taxa, further research focused on attractiveness of visual (e.g., color) and physical constraint characteristics (e.g., entrance hole size) of fruit fly bucket traps to nontarget insects are needed to devise a more environmentally friendly trap (Howarth and Howarth 2000, Uchida et al. 2003).

Among the 1,084 nontarget species and morphospecies captured by all trap types, data for three species and one morphospecies of scavenger flies, one species of plant-feeding fly, one species each of sweet- and lipid-feeding ants, which were captured in significant ($P < 0.05$) numbers are presented herein. For *Desmometopa tarsalis* Loew (Diptera: Milichiidae), total captures for all periods in ethylene glycol antifreeze, propylene glycol antifreeze, mineral oil, and control traps, respectively, were 0, 21, 7, and 58 insects. Fixed effects of period ($F = 8.79$, df = 3, 20.7; $P < 0.0006$) and attractant trap type × period interaction ($F = 3.76$, df = 6, 20.7; $P = 0.0109$) were significant. Significantly greater numbers of *D. tarsalis* were captured in propylene glycol antifreeze (14-, 21-, and 28-d trapping periods), mineral oil (21-d trapping period), and control (14-, 21-, and 28-d trapping periods) traps than in ethylene glycol antifreeze traps. Our results indicate that *D. tarsalis* is more attracted to propylene glycol antifreeze, mineral oil, and decaying insects than to ethylene glycol antifreeze. Zero captures of *D. tarsalis* in only ethylene glycol antifreeze traps within 14-, 21-, and 28-d trapping periods seem to indicate that *D. tarsalis* is repelled by the fluid. As for control traps, significantly greater capture rates increased with increased length of trapping periods (Table 1), whereas other attractant trap type capture rates decreased, indicating that *D. tarsalis* responds to accumulation of decaying insects. This finding concurs with that of Kido et al. (1996) who found that abundance of *D. tarsalis*, a carrion-associated species, was positively correlated with accumulation of captured methyl eugenol responding drosophilid flies, *Drosophila immigrans* Sturtevant and *Drosophila suzukii* (Mastumura), in dry methyl eugenol bucket traps.

Total captures of *Megaselia scalaris* (Loew) (Diptera: Phoridae) for all periods in ethylene glycol antifreeze, propylene glycol antifreeze, mineral oil, and control traps, respectively, were 56, 24, 1, and 3 insects, respectively. Fixed effects of period ($F = 7.62$, df = 3, 24.3; $P < 0.0009$) and attractant trap type × period interaction ($F = 3.73$, df = 9, 24.2; $P = 0.0046$) were significant. Ethylene glycol antifreeze (21- and 28-d trapping periods) and propylene glycol antifreeze (21-d trapping period) traps captured significantly higher numbers of *M. scalaris* than did mineral oil and control traps. These results suggest that *M. scalaris* is attracted to ethylene glycol- and propylene glycol antifreeze. Because mineral oil and control trap captures were not significantly different, we suspect that decaying insects are not attractive to *M. scalaris.* Our findings differ from those of Kido et al. (1996) who found that accumulation of two species of methyl eugenol responding drosopilids, *D. immigrans* and *D. suzuki*, in dry bucket traps served as sources of attraction for an undetermined, carrion-associated species of *Megaselia.* Furthermore, all Hawaiian species in the genus *Megaselia* are scavengers and breed in decaying plant and animal humus (Hardy 1964). This disparity in results may be associated with total number of captured insects in a trap. Kido et al. (1996) found that an increase in numbers of two species of drosophilids were positively correlated with an increase with *B. dorsalis* captured in methyl eugenol bucket traps. In addition, our result differs from those of Asquith and Kido (1994) who tested the response of nontarget insects to rain protected methyl eugenol-baited pitfall traps with ethylene glycol as a preservative and reported that methyl eugenol was attractive to an unidentified species of *Megaselia.* Apparently, their result was confounded by ethylene glycol in pitfall traps.

Total trap captures of *Lonchaea striatifrons* Malloch (Diptera: Lonchaeidae) for all periods in ethylene glycol antifreeze, propylene glycol antifreeze, mineral oil, and control traps, respectively, were 74, 207, 0, and 0 insects. Fixed effects of period ($F = 26.61$, df = 3, 11.6; $P < 0.0001$) and attractant trap type x period interaction ($F = 4.30$, df = 3, 11.6; $P = 0.0293$) were significant. Significantly more *L. striatifrons* were captured in traps containing propylene glycol antifreeze than in ethylene glycol antifreeze (21-d trapping period). Additionally, ethylene glycol antifreeze (28-d trapping period) and propylene glycol antifreeze (21- and 28-d trapping period) captured significantly more *L. striatifrons,* than did mineral oil and control traps. These findings suggest that ethylene glycol antifreeze and propylene glycol antifreeze are more attractive to *L. striatifrons* than to mineral oil and decaying insects. Because *L. striatifrons* is known to breed in rotting plants (Hardy and Delfinado 1980), it seems that decaying insects are not attractive, because trap captures were significantly lower for both mineral oil and control traps.

Total captures of chloropid sp. 2 (Diptera: Chloropidae) for all periods in ethylene glycol antifreeze, propylene glycol antifreeze, mineral oil, and control traps, respectively, were 4, 2, 0, and 0 insects. Fixed effect of attractant trap type × period interaction (F = 5.24, df = 3, 14.1; P = 0.0123) was significant. Traps containing ethylene glycol antifreeze (28-d trapping period) captured significantly more chloropid sp. 2 than mineral oil and control traps. Our results suggest that chloropid sp. 2 is attracted to ethylene glycol. Significantly lower captures of chloropid sp. 2, which is a plant feeder (Hardy and Delfinado 1980), in both mineral oil and control traps suggest that this morphospecies is not attracted to decaying insects.

Total captures of *Atherigona orientalis* Schiner (Diptera: Muscidae) for all periods in ethylene glycol antifreeze, propylene glycol antifreeze, mineral oil, and control traps, respectively, were 0, 6, 1, and 0 insects. Fixed effect of attractant trap type × period interaction (F = 5.59, df = 3, 11.3; P = 0.0135) was significant. Significantly greater numbers of *A. orientalis* were captured in propylene glycol antifreeze (21 d trapping period) than in ethylene glycol antifreeze and control traps. These results suggest that propylene glycol antifreeze is more attractive to *A. orientalis* than ethylene glycol antifreeze and decaying insects. Significantly lower captures of *A. orientalis* in control traps suggest that this species is not attracted to decaying insects. Our finding differs from that of Kido et al. (1996) who reported that *A. orientalis,* a carrion-associated species, was attracted to dead *B. dorsalis* in methyl eugenol-baited bucket traps. They surmised that *B. dorsalis* was the actual source of attraction. Conversely, previous authors (Bohart and Gressitt 1951, Hardy 1981) reported that *A. orientalis* is thought to be a predator that lives in all sorts of decaying animal and plant matter. This conflict in results cannot be explained by our data and requires further research.

Traps containing ethylene glycol antifreeze, propylene glycol antifreeze, mineral oil, and control traps, respectively, for all periods captured a total of 13, 31, 0, and 0 insects of *Monomorium floricola* (Jerdon) (Hymenoptera: Formicidae). Fixed effect of attractant trap type x period interaction (F = 4.57, df = 3, 12.5; P = 0.0224) was significant. Methyl eugenol traps containing propylene glycol antifreeze (7-d trapping period) captured significantly greater numbers of *M. floricola* than mineral oil and control traps. Thus, propylene glycol antifreeze is more attractive to *M. floricola* than decaying insects. Warner and Scheffrahn (2004) reported that *M. floricola,* a sweet-feeding ant, favored sugar water (sucrose) over deionized water. Additionally, because *M. floricola* was captured in significantly lower numbers in both mineral oil and control traps, this species does not seem to be primarily attracted to decaying insects.

Ethylene glycol antifreeze, propylene glycol antifreeze, mineral oil, and control traps, respectively, for all periods captured a total of 10, 1, 3, and 0 insects of white-footed ant, *Technomyrmex albipes* (F. Smith) (Hymenoptera: Formicidae). Fixed effect of attractant trap type × period interaction (F = 3.55, df = 6, 18.4; P = 0.0164) was significant. Ethylene glycol antifreeze traps (14-d trapping period) captured significantly more of *T. albipes* than control traps. This result suggests that *T. albipes* is more attracted to ethylene glycol antifreeze than mineral and decaying insects. Additionally, Eow et al. (2005) determined that lipid-based food (peanut oil) was favored by *T. albipes.* The lipid-feeding habit of *T. albipes* and significantly lower captures in control traps suggest that this species is not attracted primarily to decaying insects.

As for the length of field exposure of attractant type, decaying *B. dorsalis* in control traps attracted, respectively, significantly lower numbers of five taxa of decaying plant matter scavengers and plant-feeding flies and lipid and sweet-feeding ants during 21- and 28-, and 7- and 14-d trapping periods. Mineral oil attracted scavenger flies *M. scalaris, L. striatifrons,* and chloropid sp. 2 during 21- and 28-d trapping periods, and sweet-feeding *T. albipes* during a 7-d trapping period in significantly lowest numbers.

Because the control trap configuration captured all species and morphospecies, except for *D. tarsalis,* in significantly lower numbers (Table 1), this trap can be considered as suitable for trapping *B. dorsalis* in environmentally sensitive habitats. However, the increase in the number of nontarget insects attracted to control traps may be correlated with an increase in the number of *B. dorsalis* captures (Kido et al. 1996). Alternately, mineral oil traps, which captured all nontarget species and morphospecies, except *D. tarsalis, A. orientalis,* and *T. albipes* in significantly fewer numbers, was the second least attractive trap. Thus, mineral oil, which can be safely ingested orally by humans, can be used in bucket traps with the same margin of safety as control traps as long as the fluid is not spilled in its surrounding environment. Nevertheless, mineral oil traps require more frequent servicing than control traps to avoid capturing more insects than the added mineral oil can physically contain. Because of the aforementioned limitations of using both control and mineral oil traps, a different line of research is needed to modify the control trap in such a way as to reduce its attractiveness to nontarget insects. Presently, research is underway to determine the attractiveness of both visual and physical constraint characteristics of bucket traps. Additionally, more research is needed to develop a better trap, which can serve as a tool, to evaluate the attraction effects of endemic species of nontarget insect populations.

In conclusion, propylene glycol antifreeze was determined to be the most attractive to *B. dorsalis.* Thus, the propylene glycol antifreeze bucket trap is suited for use where endemic insects are known to be absent. However, because mineral oil minimizes release of decaying insect volatiles into the surrounding air, the mineral oil bucket trap is the best alternative for use in environmentally sensitive habitats. Based on our results, mineral oil bucket traps are suited for minimizing captures of scavenger flies, plant-feeding flies, lipid-feeding ants, and sweet-feeding ants, respectively, for 28-, 21-, 14-, and 7-d trapping periods in environments where these types of insects exist. Additionally, because both propylene glycol and mineral oil in traps can each act as a collecting agent, a toxicant can be withheld, and thereby eliminate a potential source of mammal poison and environmental contamination.

Acknowledgments

We thank John D. Stark (Washington State University, Pullallup, WA) and Robert G. Hollingsworth and Grant T. McQuate (USDA–ARS, PBARC, Hilo, HI) for critical review of an earlier version of this manuscript.

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Received 11 August 2006; accepted 27 November 2006.